Exploration of Double Clad Fibers for Increased Stability of Bidirectional Free Space Optical Links

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Motivation

Motivation: Free space optical links are needed for space and aeronautic communication applications that are:

- Bidirectional and simultaneous (full duplex)
- high data rate
- low size, weight, and power (SWaP)
- low cost

Challenge: pointing the laser beam with enough accuracy to create a high speed link. Commonly solved by components that:

- Increase cost
- Increase SWaP

Introduction

Goals:

- Eliminate/reduce active components (gimbals, amplifiers, etc.)
  - Strategy: Increase field of view to reduce pointing accuracy requirements
- Reduce the amount of optical components
  - Strategy: Share the optical transmit and receive paths

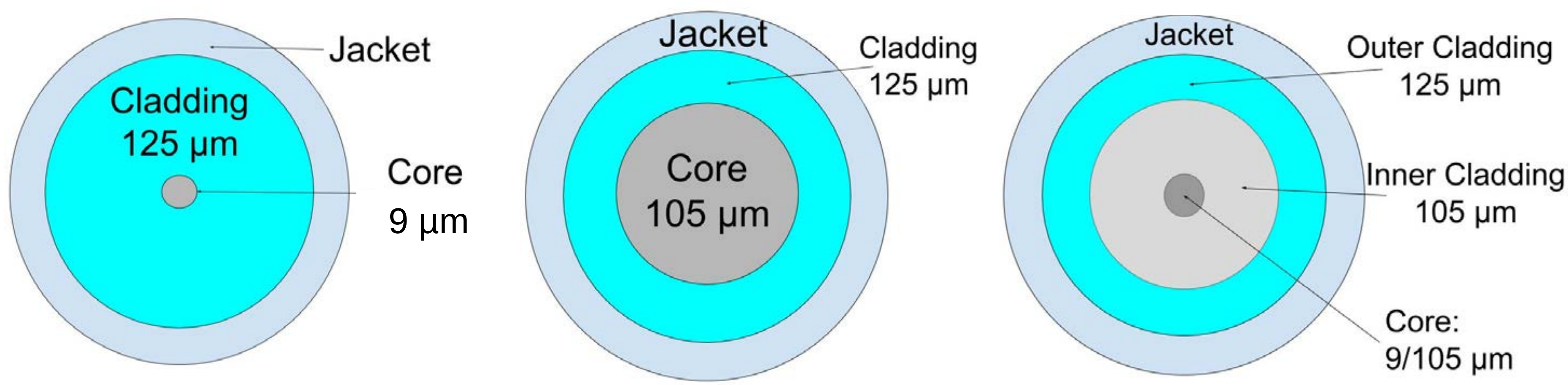
Application Focus: FSOL with fiber coupled detectors

- Fiber numerical aperture is the main driver of the pointing accuracy

Double Clad Fibers (DCF): potential to implement both strategies

- Compared performance to other fibers in 20 meter FSOL
  - Reduced pointing accuracy requirement
  - Improved received power stability

Double Clad Fibers



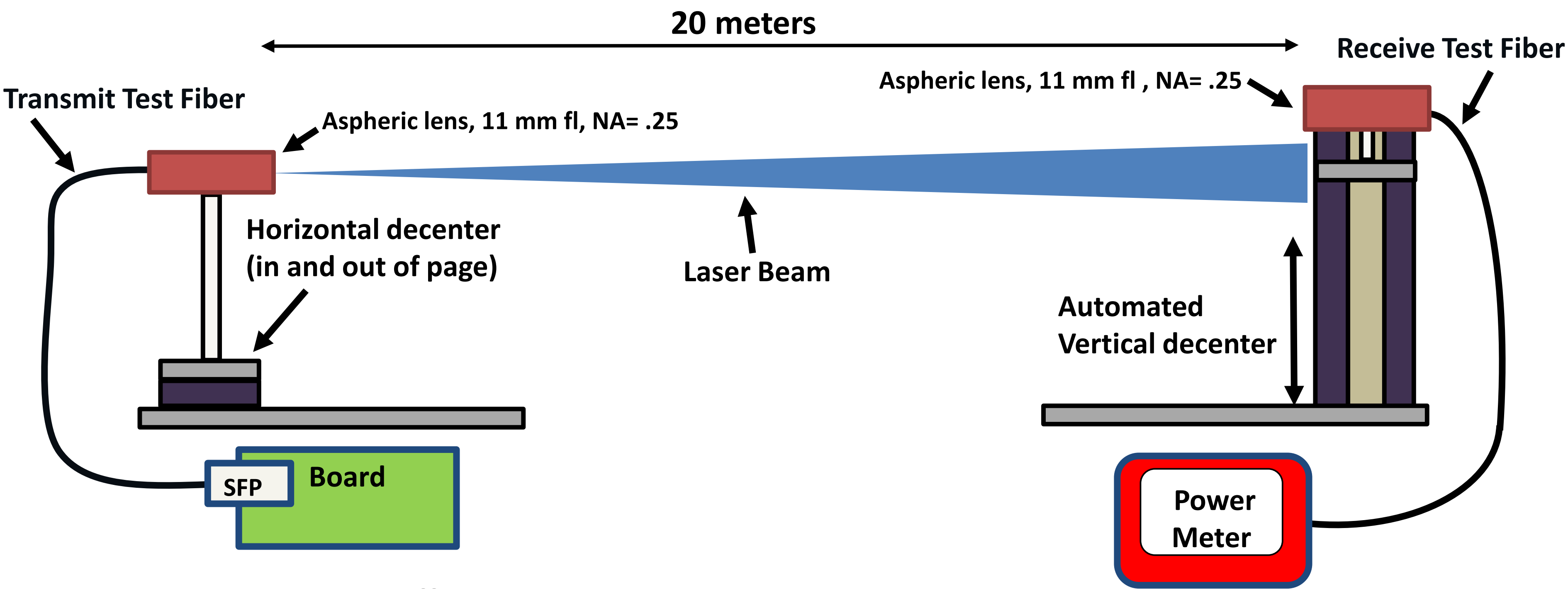
Single Mode Fiber **Multi Mode Fiber** **Double Clad Fiber**

Double Clad fiber can transmit from a single mode fiber and receive through a multimode fiber.

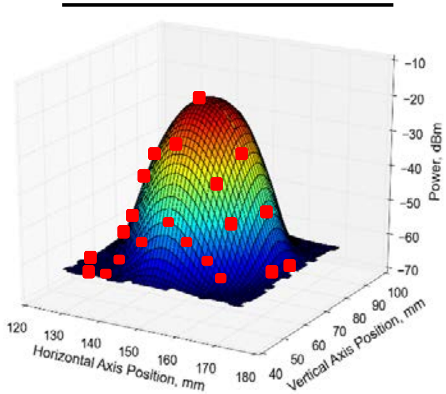
Enables both:

- Increase receive fiber core → improved field of view
- Smooth transmit profile → improved received power stability

Experimental Setup: Pointing Accuracy Tolerance

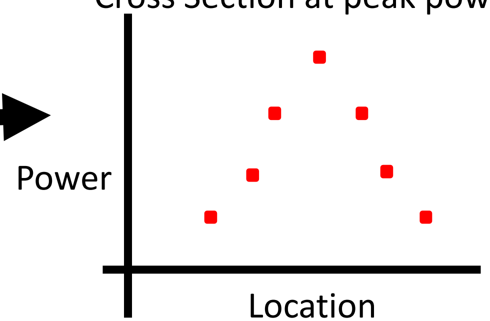


Data collection



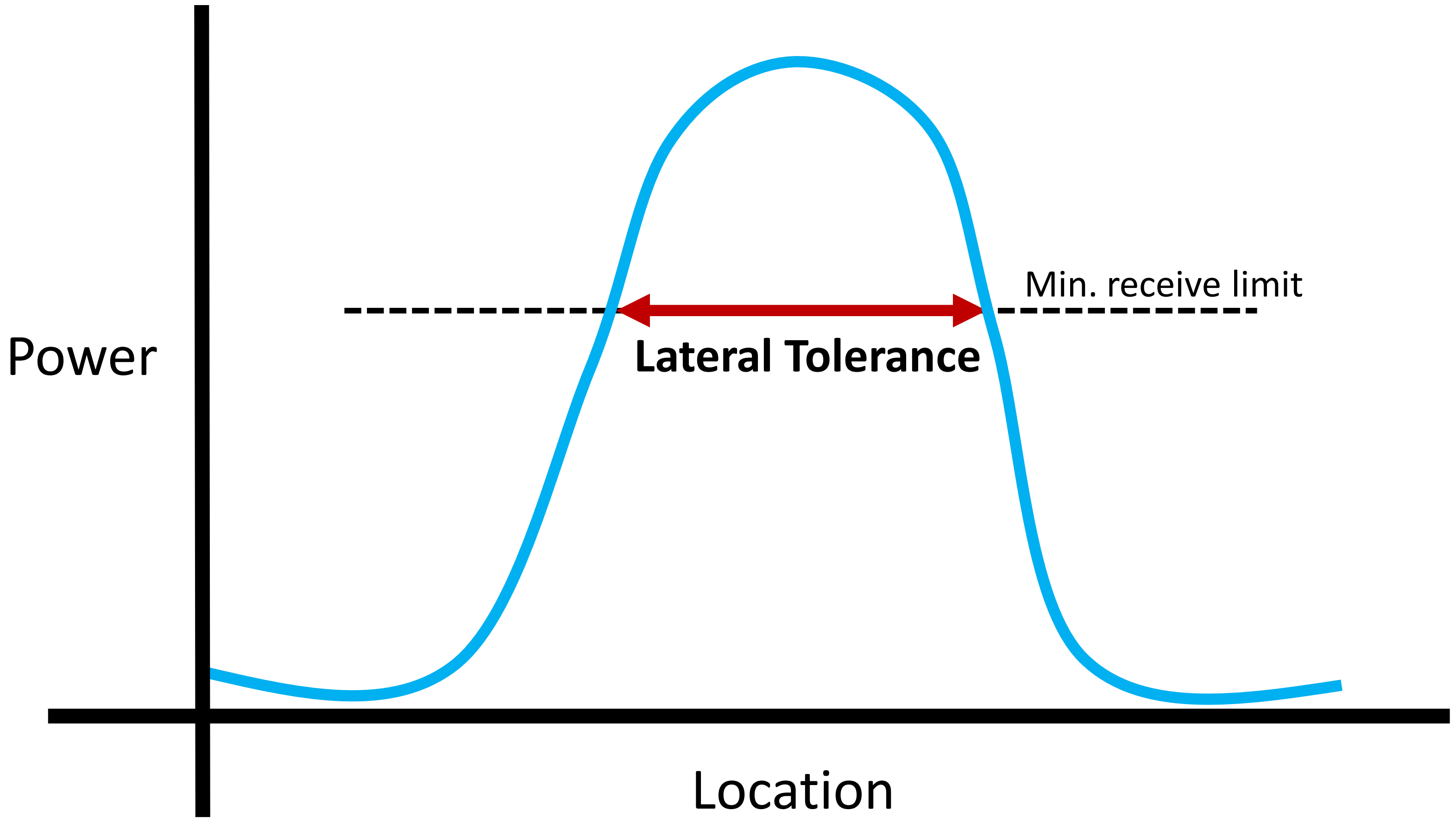
Data Analysis

Cross Section at peak power

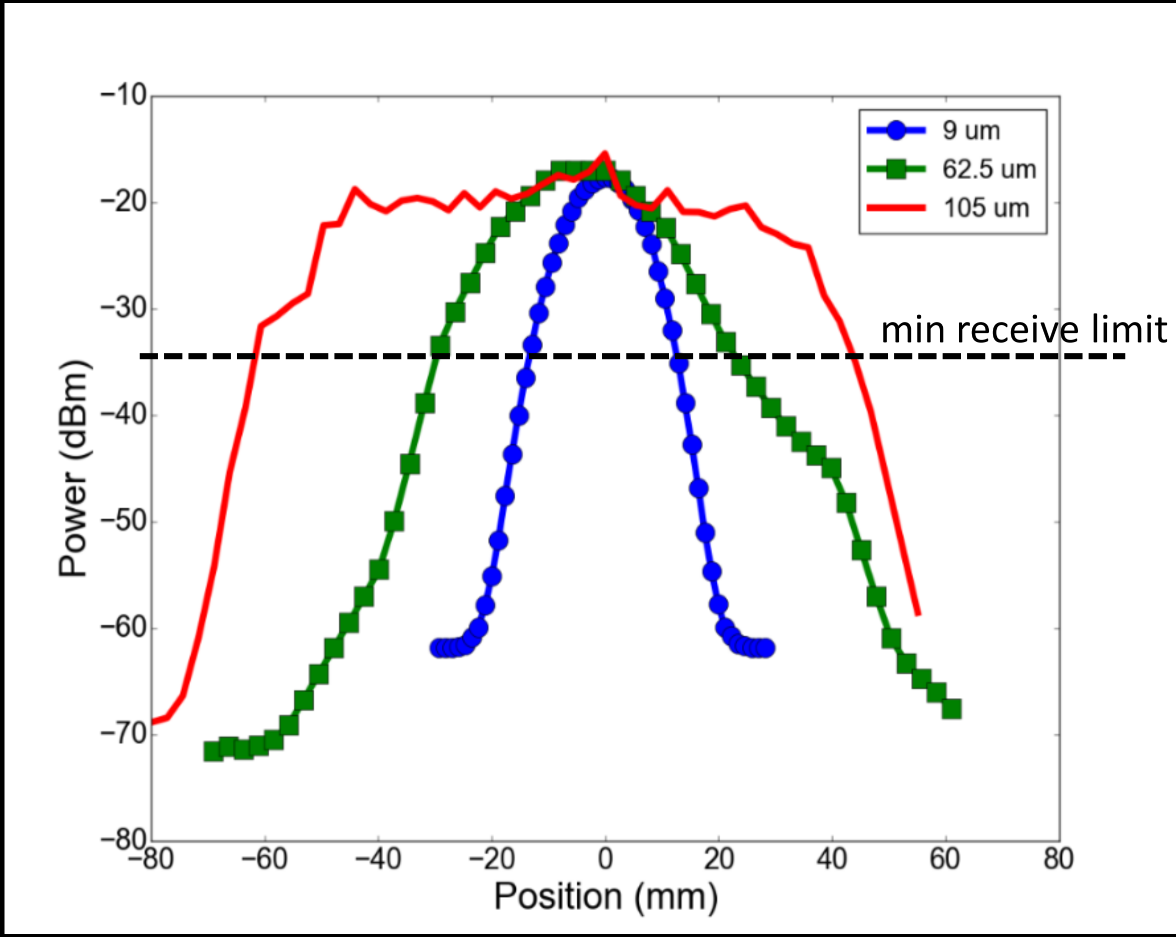


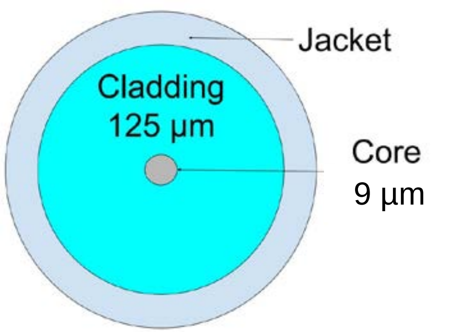
Definition of Pointing Accuracy Tolerance

Lateral misalignment tolerance (*Pointing Accuracy Tolerance*)= distance over which received power is above threshold for error-free link

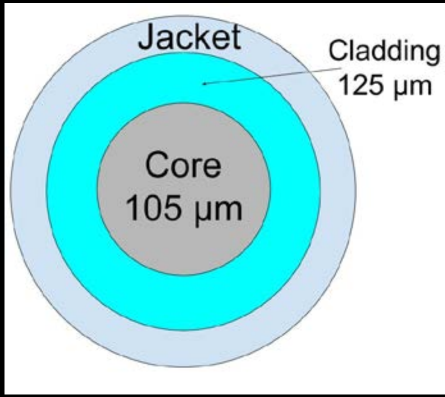


Background
Larger Core → Reduces Pointing Requirement





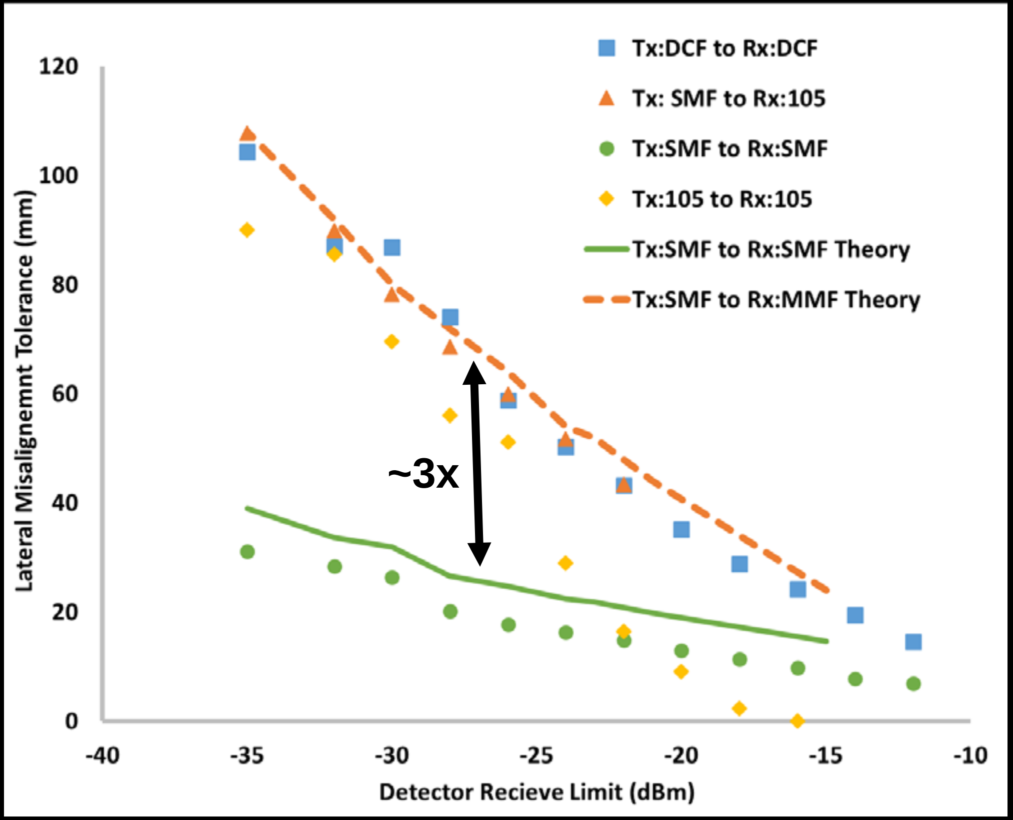
Single Mode Fiber (SMF)

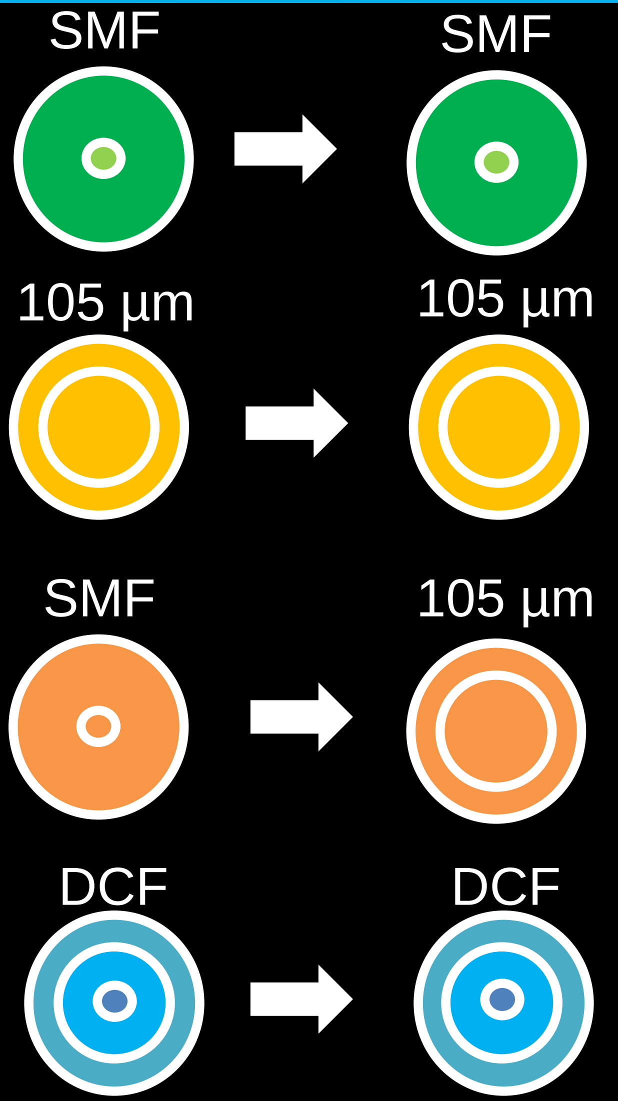


105 µm Mode Fiber

Increasing core fiber → increases the field of view → increases the pointing accuracy tolerance

Pointing Accuracy Tolerance of Double Clad Fibers

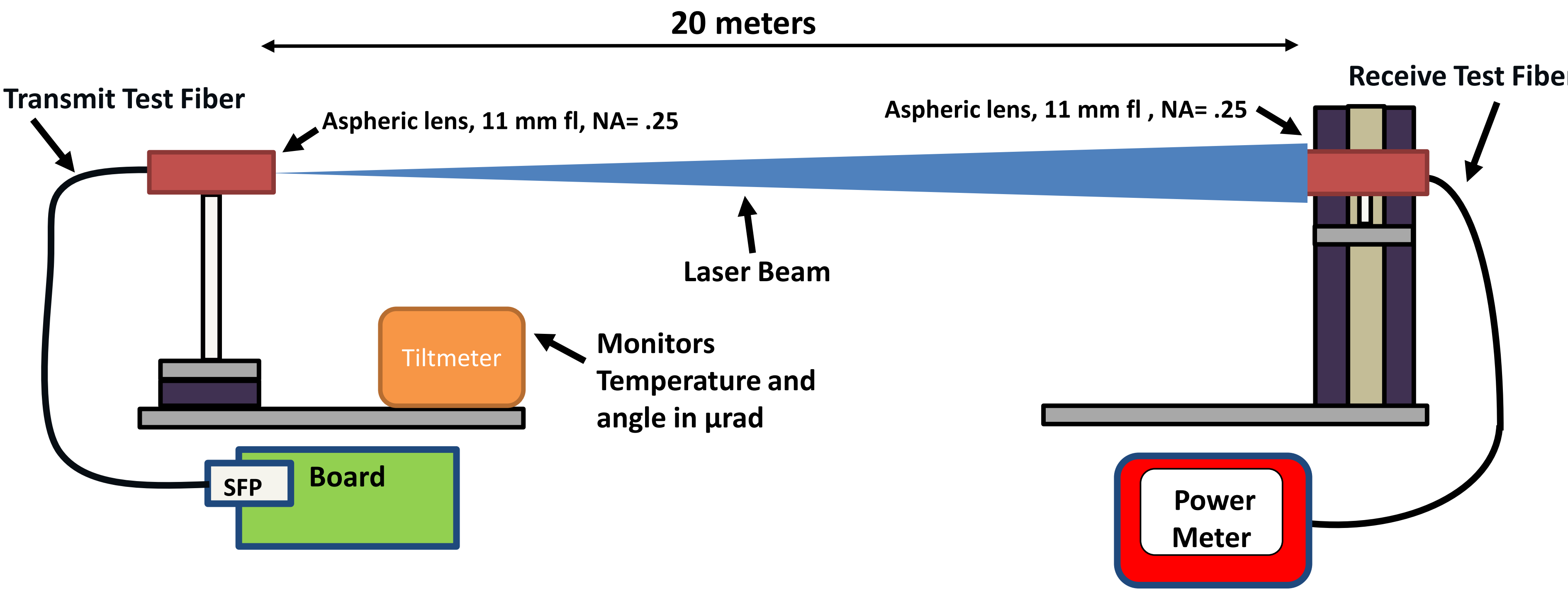




DCF to DCF lateral misalignment tolerance:

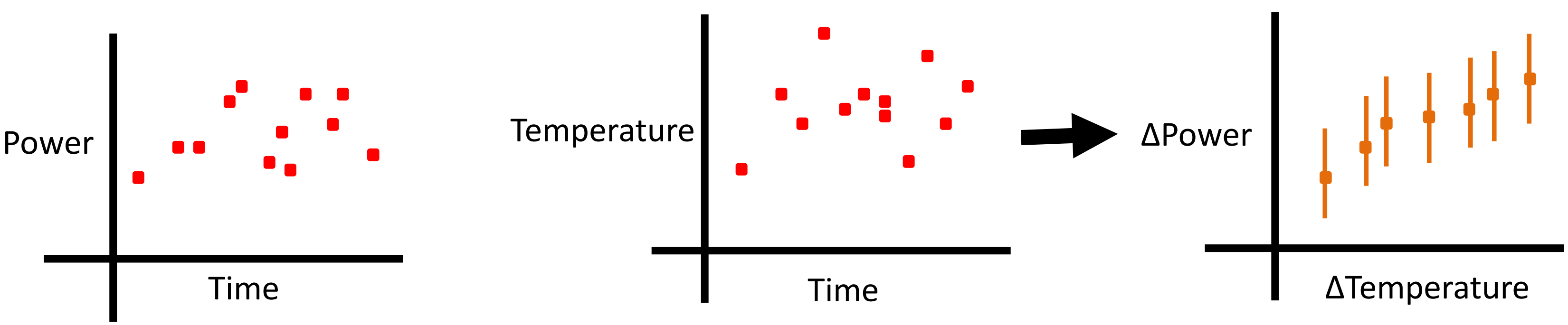
- 3 times > SMF to SMF at < -22 dBm
- > 105 micron to 105 micron
- = SMF transmitting to a 105 micron

Experimental Setup: Received Power Stability due to Small Environmental Changes



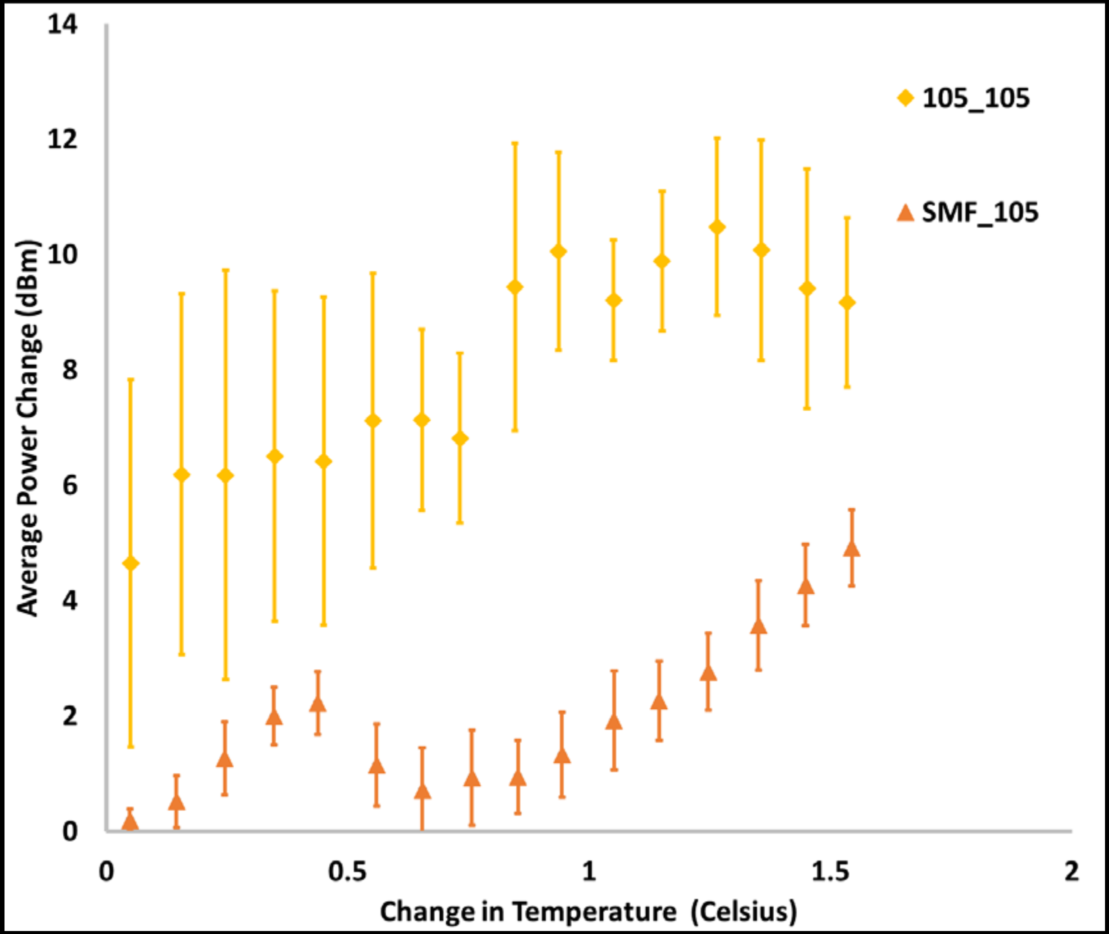
Data collection

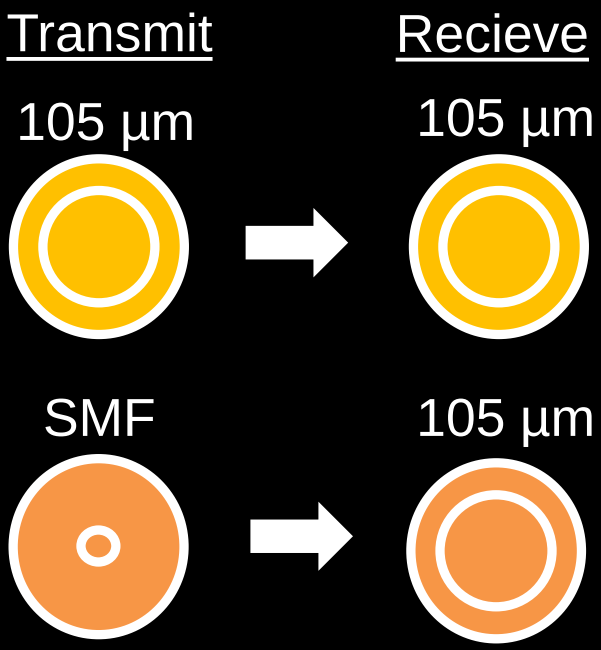
Data Analysis



Background

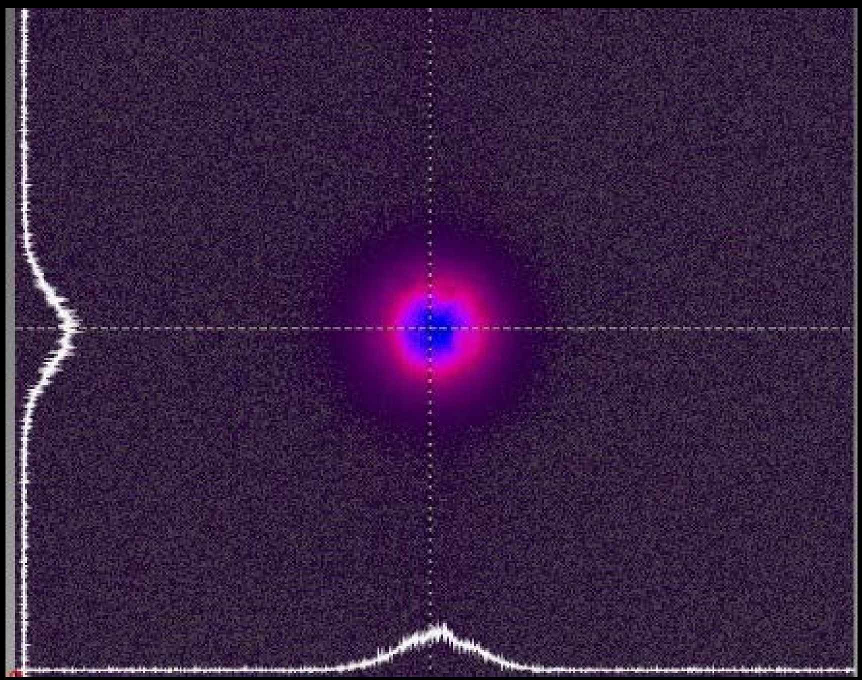
Larger Transmit Core → Lower Received Power Stability



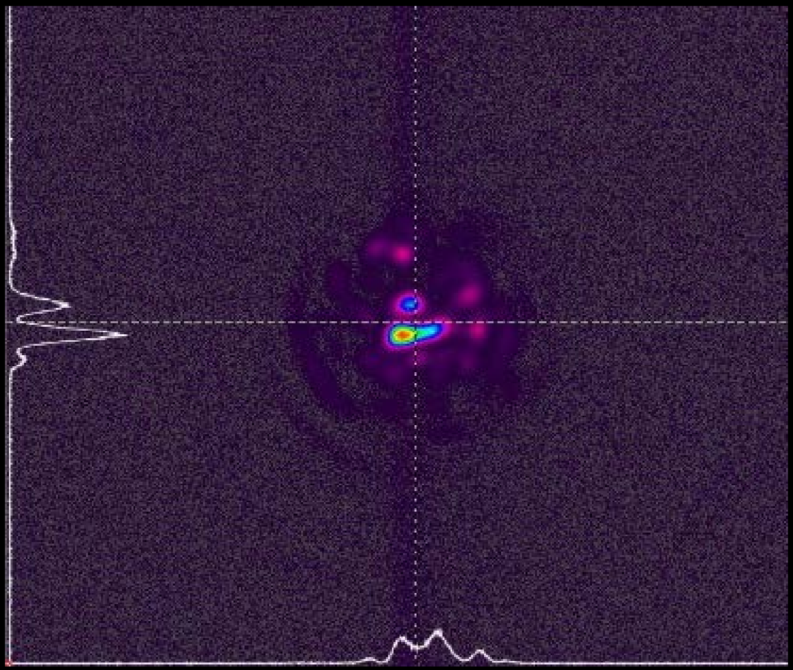


When the transmit fiber core is increased small environmental changes have a larger effect on the received power.

Because… the transmitted beam profile



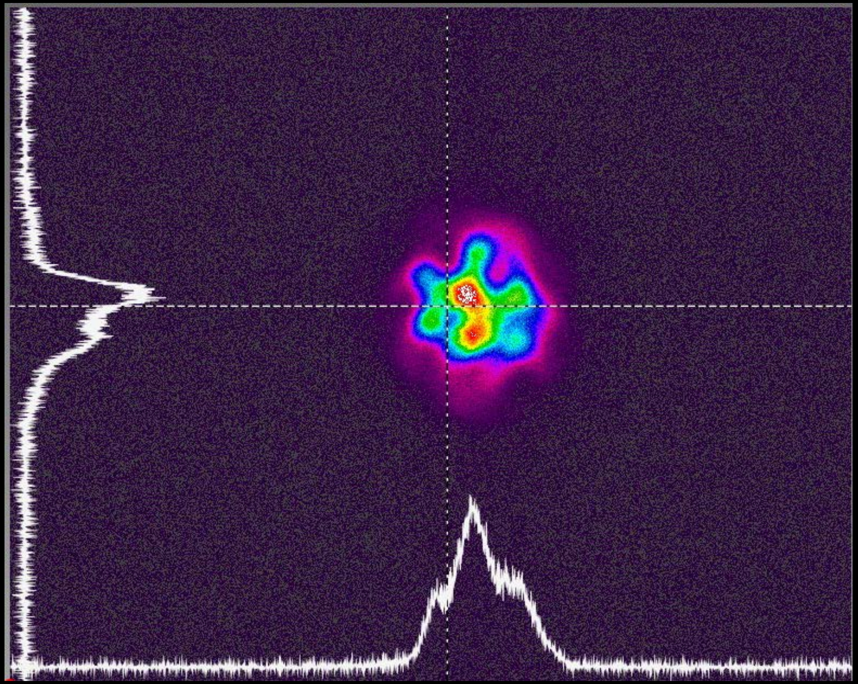
Single Mode Fiber Transmitted Profile



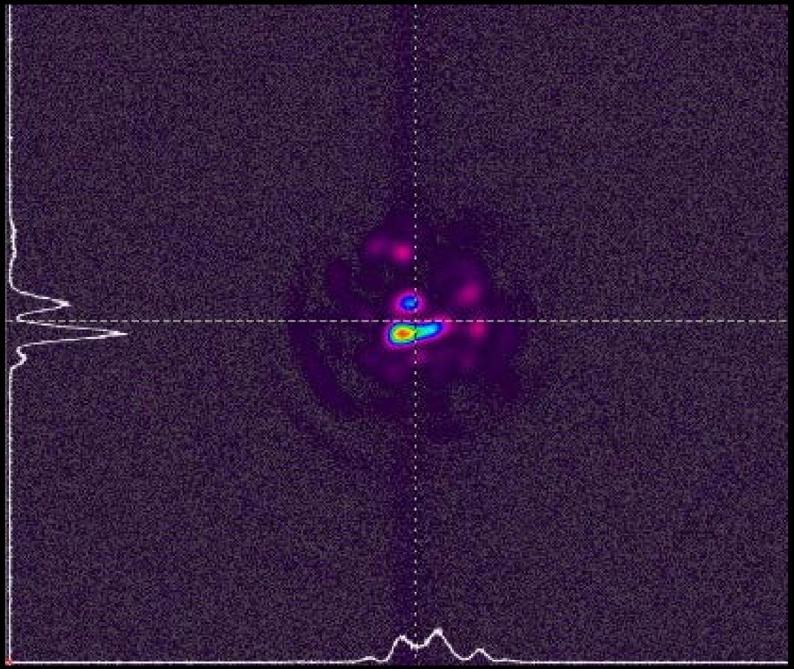
Multi Mode Fiber Transmitted Profile

Transmitted beam profile of MMF has many hills and valleys causing small changes in alignment to produced large changes in received power.

DCF transmitted beam profile



Double Clad Fiber Transmitted Profile

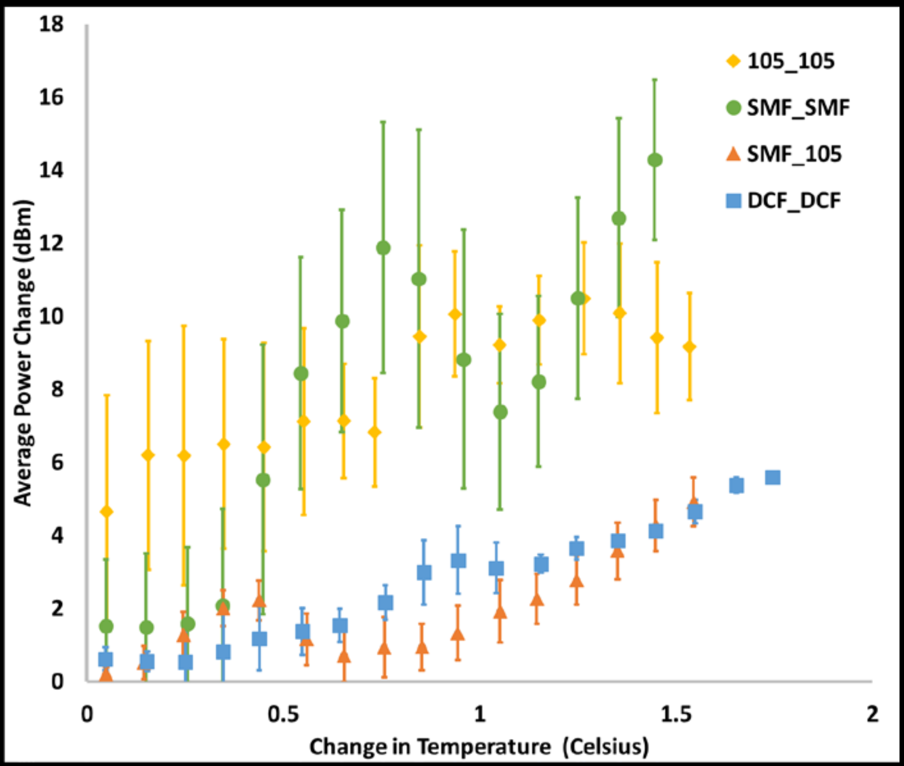


Multi Mode Fiber Transmitted Profile

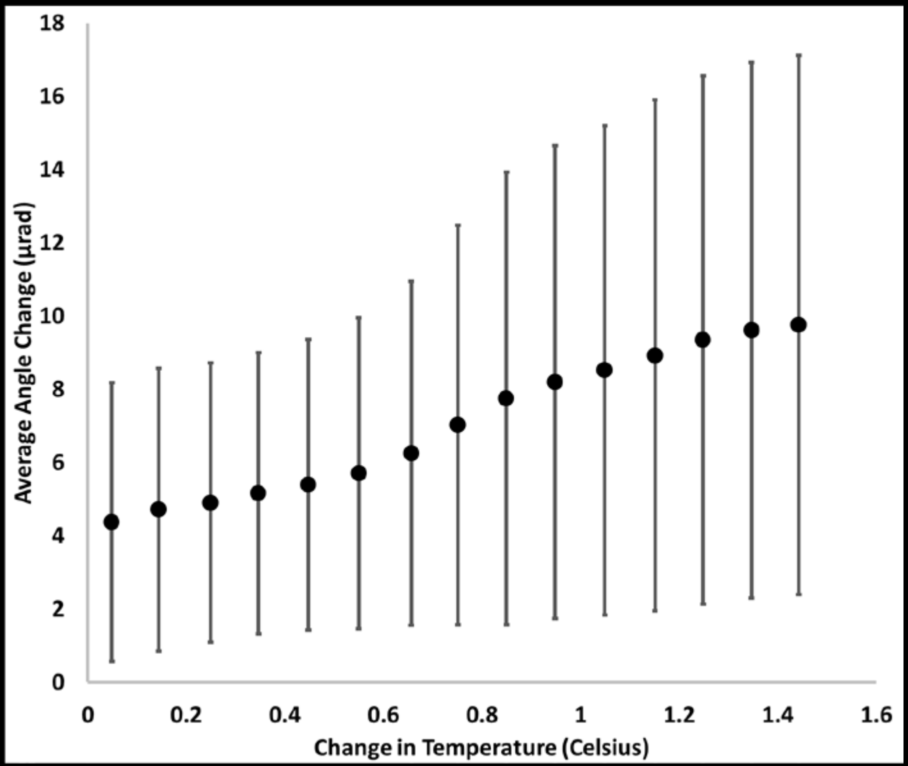
Transmitted beam profile of DCF is close to the SMF and has much less hills and valleys than the MMF .

Received Power Stability of Double Clad Fibers

Effect of temperature on received power



Effect of temperature on transmit table angle



DCF to DCF power received stability:

- > 105 micron to 105 micron and SMF to SMF
- = SMF transmitting to a 105 micron

Conclusion

- DCFs match performance of SMF → MMF of same core and first cladding size
  - pointing accuracy tolerance
  - received power stability
- DCFs enables full duplex communication with:
  - 1 optical path → reducing optics → reducing SWaP
  - pointing requirement reduction → reduce/eliminate active components → reduce cost and SWaP
- DCF should be considered for applications where SWaP is critical

Future Work

- Bit error rate performance of DCFs
- Study DCFs pointing accuracy in terms of tilt
- Study effect of range on FSOLs with DCFs
- Investigate performance of DCF couplers

ACKNOWLEDGEMENTS

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